# Integrated Circuit, True RMS-to-DC Converter

# AD536A

## FEATURES

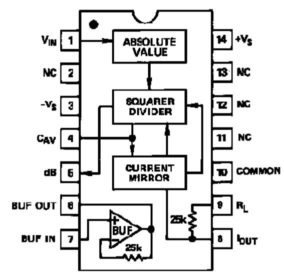
**True RMS-to-DC Conversion**
**Laser-Trimmed to High Accuracy**
- **0.2% max Error (AD536AK)**
- **0.5% max Error (AD536AJ)**

**Wide Response Capability:**
- **Computes RMS of AC and DC Signals**
- **450 kHz Bandwidth: V rms > 100 mV**
- **2 MHz Bandwidth: V rms > 1 V**
- **Signal Crest Factor of 7 for 1% Error**

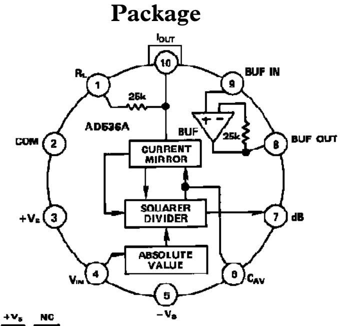
**dB Output with 60 dB Range**
**Low Power: 1.2 mA Quiescent Current**
**Single or Dual Supply Operation**
**Monolithic Integrated Circuit**
**–55°C to +125°C Operation (AD536AS)**

## PIN CONFIGURATIONS AND FUNCTIONAL BLOCK DIAGRAMS

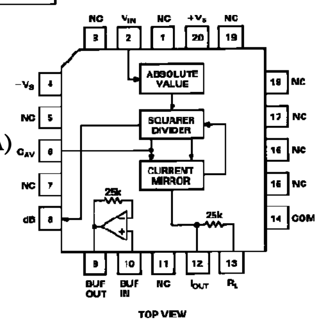
**TO-116 (D-14) and Q-14 Package**




**TO-100 (H-10A) Package**




**LCC (E-20A) Package**




## PRODUCT DESCRIPTION

The AD536A is a complete monolithic integrated circuit which performs true rms-to-dc conversion. It offers performance which is comparable or superior to that of hybrid or modular units costing much more. The AD536A directly computes the true rms value of any complex input waveform containing ac and dc components. It has a crest factor compensation scheme which allows measurements with 1% error at crest factors up to 7. The wide bandwidth of the device extends the measurement capability to 300 kHz with 3 dB error for signal levels above 100 mV.

An important feature of the AD536A not previously available in rms converters is an auxiliary dB output. The logarithm of the rms output signal is brought out to a separate pin to allow the dB conversion, with a useful dynamic range of 60 dB. Using an externally supplied reference current, the 0 dB level can be conveniently set by the user to correspond to any input level from 0.1 to 2 volts rms.

The AD536A is laser trimmed at the wafer level for input and output offset, positive and negative waveform symmetry (dc reversal error), and full-scale accuracy at 7 V rms. As a result, no external trims are required to achieve the rated accuracy of the unit.

There is full protection for both inputs and outputs. The input circuitry can take overload voltages well beyond the supply levels. Loss of supply voltage with inputs connected will not cause unit failure. The output is short-circuit protected.

The AD536A is available in two accuracy grades (J, K) for commercial temperature range (0°C to +70°C) applications, and one grade (S) rated for the –55°C to +125°C extended range. The AD536AK offers a maximum total error of ±2 mV ±0.2% of reading, and the AD536AJ and AD536AS have maximum errors of ±5 mV ±0.5% of reading. All three versions are available in either a hermetically sealed 14-pin DIP or 10-pin TO-100 metal can. The AD536AS is also available in a 20-pin hermetically sealed ceramic leadless chip carrier.

## PRODUCT HIGHLIGHTS

1. The AD536A computes the true root-mean-square level of a complex ac (or ac plus dc) input signal and gives an equivalent dc output level. The true rms value of a waveform is a more useful quantity than the average rectified value since it relates directly to the power of the signal. The rms value of a statistical signal also relates to its standard deviation.
2. The crest factor of a waveform is the ratio of the peak signal swing to the rms value. The crest factor compensation scheme of the AD536A allows measurement of highly complex signals with wide dynamic range.
3. The only external component required to perform measurements to the fully specified accuracy is the capacitor which sets the averaging period. The value of this capacitor determines the low frequency ac accuracy, ripple level and settling time.
4. The AD536A will operate equally well from split supplies or a single supply with total supply levels from 5 to 36 volts. The one milliampere quiescent supply current makes the device well-suited for a wide variety of remote controllers and battery powered instruments.
5. The AD536A directly replaces the AD536 and provides improved bandwidth and temperature drift specifications.

REV. A



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# AD536A–SPECIFICATIONS (@ +25°C, and ±15 V dc unless otherwise noted)

| Model | AD536AJ Min | Typ | Max | AD536AK Min | Typ | Max | AD536AS Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|---|---|---|
| TRANSFER FUNCTION | | $V_{OUT} = \sqrt{avg.(V_{IN})^2}$ | | | $V_{OUT} = \sqrt{avg.(V_{IN})^2}$ | | | $V_{OUT} = \sqrt{avg.(V_{IN})^2}$ | | |
| CONVERSION ACCURACY | | | | | | | | | | |
| Total Error, Internal Trim[1] (Figure 1) | | | **±5 ±0.5** | | | **±2 ±0.2** | | | **±5 ±0.5** | mV ± % of Reading |
| vs. Temperature, $T_{MIN}$ to +70°C | | | ±0.1 ±0.01 | | | ±0.05 ±0.005 | | | **±0.1 ±0.005** | mV ± % of Reading/°C |
| +70°C to +125°C | | | | | | | | | **±0.3 ±0.005** | mV ± % of Reading/°C |
| vs. Supply Voltage | | ± 0.1 ±0.01 | | | ±0.1 ±0.01 | | | ± 0 1 ±0.01 | | mV ± % of Reading/V |
| dc Reversal Error | | ±0.2 | | | ±0.1 | | | ±0.2 | | ± % of Reading |
| Total Error, External Trim[1] (Figure 2) | | ±3 ±0.3 | | | ±2 ±0.1 | | | ±3 ±0.3 | | mV ± % of Reading |
| ERROR VS. CREST FACTOR[2] | | | | | | | | | | |
| Crest Factor 1 to 2 | | Specified Accuracy | | | Specified Accuracy | | | Specified Accuracy | | |
| Crest Factor = 3 | | –0.1 | | | –0.1 | | | –0.1 | | % of Reading |
| Crest Factor = 7 | | –1.0 | | | –1.0 | | | –1.0 | | % of Reading |
| FREQUENCY RESPONSE[3] | | | | | | | | | | |
| Bandwidth for 1% Additional Error (0.09 dB) | | | | | | | | | | |
| $V_{IN}$ = 10 mV | | 5 | | | 5 | | | 5 | | kHz |
| $V_{IN}$ = 100 mV | | 45 | | | 45 | | | 45 | | kHz |
| $V_{IN}$ = 1 V | | 120 | | | 120 | | | 120 | | kHz |
| ±3 dB Bandwidth | | | | | | | | | | |
| $V_{IN}$ = 10 mV | | 90 | | | 90 | | | 90 | | kHz |
| $V_{IN}$ = 100 mV | | 450 | | | 450 | | | 450 | | kHz |
| $V_{IN}$ = 1 V | | 2.3 | | | 2.3 | | | 2.3 | | MHz |
| AVERAGING TIME CONSTANT (Figure 5) | | 25 | | | 25 | | | 25 | | ms/µF CAV |
| INPUT CHARACTERISTICS | | | | | | | | | | |
| Signal Range, ±15 V Supplies | | | | | | | | | | |
| Continuous rms Level | | 0 to 7 | | | 0 to 7 | | | 0 to 7 | | V rms |
| Peak Transient Input | | | ±20 | | | ±20 | | | ±20 | V peak |
| Continuous rms Level, ±5 V Supplies | | 0 to 2 | | | 0 to 2 | | | 0 to 2 | | V rms |
| Peak Transient Input, ±5 V Supplies | | | ±7 | | | ±7 | | | ±7 | V peak |
| Maximum Continuous Nondestructive Input Level (All Supply Voltages) | | | ±25 | | | ±25 | | | ±25 | V peak |
| Input Resistance | 13.33 | 16.67 | 20 | 13.33 | 16.67 | 20 | 13.33 | 16.67 | 20 | kΩ |
| Input Offset Voltage | | 0.8 | ±2 | | 0.5 | ±1 | | 0.8 | ±2 | mV |
| OUTPUT CHARACTERISTICS | | | | | | | | | | |
| Offset Voltage, $V_{IN}$ = COM (Figure 1) | | ±1 | **±2** | | ±0.5 | **±1** | | | **+2** | mV |
| vs. Temperature | | ±0.1 | | | ±0.1 | | | | **±0.2** | mV/°C |
| vs. Supply Voltage | | ±0.1 | | | ±0.1 | | | ±0.2 | | mV/V |
| Voltage Swing, ±15 V Supplies | **0 to +11** | +12.5 | | **0 to +11** | +12.5 | | **0 to +11** | +12.5 | | V |
| ±5 V Supply | 0 to +2 | | | 0 to +2 | | | 0 to +2 | | | V |
| dB OUTPUT (Figure 13) | | | | | | | | | | |
| Error, $V_{IN}$ 7 mV to 7 V rms, 0 dB = 1 V rms | | ±0.4 | **±0.6** | | ±0.2 | **±0.3** | | ±0.5 | **±0.6** | dB |
| Scale Factor | | –3 | | | –3 | | | –3 | | mV/dB |
| Scale Factor TC (Uncompensated, see Figure 1 for Temperature Compensation) | | –0.033 | | | –0.033 | | | –0.033 | | dB/°C |
| | | +0.33 | | | +0.33 | | | +0.33 | | % of Reading/°C |
| $I_{REF}$ for 0 dB = 1 V rms | **5** | 20 | **80** | **5** | 20 | **80** | **5** | 20 | **80** | µA |
| $I_{REF}$ Range | 1 | | 100 | 1 | | 100 | 1 | | 100 | µA |
| $I_{OUT}$ TERMINAL | | | | | | | | | | |
| $I_{OUT}$ Scale Factor | | 40 | | | 40 | | | 40 | | µA/V rms |
| $I_{OUT}$ Scale Factor Tolerance | | ±10 | ±20 | | ±10 | ±20 | | ±10 | ±20 | % |
| Output Resistance | 20 | 25 | 30 | 20 | 25 | 30 | 20 | 25 | 30 | kΩ |
| Voltage Compliance | | $-V_S$ to $(+V_S$ –2.5 V) | | | $-V_S$ to $(+V_S$ –2.5 V) | | | $-V_S$ to $(+V_S$ –2.5 V) | | V |
| BUFFER AMPLIFIER | | | | | | | | | | |
| Input and Output Voltage Range | $-V_S$ to $(+V_S$ –2.5 V) | | | $-V_S$ to $(+V_S$ –2.5 V) | | | $-V_S$ to $(+V_S$ –2.5 V) | | | V |
| Input Offset Voltage, $R_S$ = 25 k | | ±0.5 | **±4** | | ±0.5 | **±4** | | ±0.5 | ±4 | mV |
| Input Bias Current | | 20 | **60** | | 20 | **60** | | 20 | **60** | nA |
| Input Resistance | | $10^8$ | | | $10^8$ | | | $10^8$ | | Ω |
| Output Current | (+5 mA, –130 µA) | | | (+5 mA, –130 µA) | | | (+5 mA, –130 µA) | | | |
| Short Circuit Current | | 20 | | | 20 | | | 20 | | mA |
| Output Resistance | | | 0.5 | | | 0.5 | | | 0.5 | Ω |
| Small Signal Bandwidth | | 1 | | | 1 | | | 1 | | MHz |
| Slew Rate[4] | | 5 | | | 5 | | | 5 | | V/µs |
| POWER SUPPLY | | | | | | | | | | |
| Voltage Rated Performance | | ±15 | | | ±15 | | | ±15 | | V |
| Dual Supply | ±3.0 | | ±18 | ±3.0 | | ±18 | ±3.0 | | ±18 | V |
| Single Supply | +5 | | +36 | +5 | | +36 | +5 | | +36 | V |
| Quiescent Current | | | | | | | | | | |
| Total $V_S$, 5 V to 36 V, $T_{MIN}$ to $T_{MAX}$ | | 1.2 | **2** | | 1.2 | **2** | | 1.2 | **2** | mA |
| TEMPERATURE RANGE | | | | | | | | | | |
| Rated Performance | 0 | | +70 | 0 | | +70 | –55 | | +125 | °C |
| Storage | –55 | | +150 | –55 | | +150 | –55 | | +150 | °C |
| NUMBER OF TRANSISTORS | | 65 | | | 65 | | | 65 | | |
| PACKAGE OPTIONS | | | | | | | | | | |
| Ceramic DIP (D-14) | | AD536AJD | | | AD536AKD | | | AD536ASH | | |
| Metal Can TO-100 (H-10A) | | AD5536AJH | | | AD536AKH | | | AD536ASH | | |
| LCC (E-20A) | | | | | | | | AD536ASE | | |

NOTES
[1]Accuracy is specified for 0 V to 7 V rms, dc or 1 kHz sine wave input with the AD536A connected as in the figure referenced.
[2]Error vs. crest factor is specified as an additional error for 1 V rms rectangular pulse input, pulse width = 200 µs.
[3]Input voltages are expressed in volts rms, and error is percent of reading.
[4]With 2k external pull-down resistor.

Specifications subject to change without notice.

Specifications shown in **boldface** are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

**ABSOLUTE MAXIMUM RATINGS**[1]

Supply Voltage
- Dual Supply . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . ±18 V
- Single Supply . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . +36 V

Internal Power Dissipation[2] . . . . . . . . . . . . . . . . . . . . 500 mW
Maximum Input Voltage . . . . . . . . . . . . . . . . . . . . ±25 V Peak
Buffer Maximum Input Voltage . . . . . . . . . . . . . . . . . . . . . $\pm V_S$
Maximum Input Voltage . . . . . . . . . . . . . . . . . . . . ±25 V Peak
Storage Temperature Range . . . . . . . . . . . . –55°C to +150°C
Operating Temperature Range
- AD536AJ/K . . . . . . . . . . . . . . . . . . . . . . . . . 0°C to +70°C
- AD536AS . . . . . . . . . . . . . . . . . . . . . . . . –55°C to +125°C

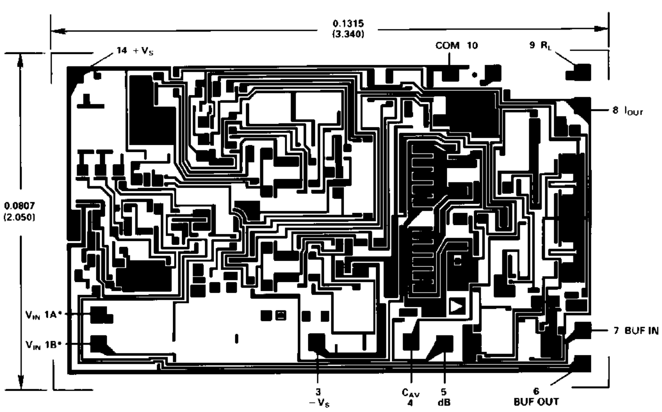
Lead Temperature Range
- (Soldering 60 sec) . . . . . . . . . . . . . . . . . . . . . . . . . +300°C

ESD Rating . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1000 V

NOTES
[1]Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
[2]10-Pin Header: $\theta_{JA}$ = 150°C/W
20-Pin LCC: $\theta_{JA}$ = 95°C/W
14-Pin Size Brazed Ceramic DIP: $\theta_{JA}$ = 95°C/W.

## CHIP DIMENSIONS AND PAD LAYOUT

Dimensions shown in inches and (mm).




PAD NUMBERS CORRESPOND TO PIN NUMBERS FOR THE TO-116 14-PIN CERAMIC DIP PACKAGE.

NOTE
*BOTH PADS SHOWN MUST BE CONNECTED TO $V_{IN}$.
THE AD536A IS AVAILABLE IN LASER TRIMMED CHIP FORM.
SUBSTRATE CONNECTED TO $-V_S$.

## ORDERING GUIDE

| Model[1] | Temperature Range | Package Description | Package Option |
|---|---|---|---|
| AD536AJD | 0°C to +70°C | Side Brazed Ceramic DIP | D-14 |
| AD536AKD | 0°C to +70°C | Side Brazed Ceramic DIP | D-14 |
| AD536AJH | 0°C to +70°C | Header | H-10A |
| AD536AKH | 0°C to +70°C | Header | H-10A |
| AD536AJQ | 0°C to +70°C | Cerdip | Q-14 |
| AD536AKQ | 0°C to +70°C | Cerdip | Q-14 |
| AD536ASD | –55°C to +125°C | Side Brazed Ceramic DIP | D-14 |
| AD536ASD/883B | –55°C to +125°C | Side Brazed Ceramic DIP | D-14 |
| AD536ASE | –55°C to +125°C | LCC | E-20A |
| AD536ASE/883B | –55°C to +125°C | LCC | E-20A |
| AD536ASH | –55°C to +125°C | Header | H-10A |
| AD536ASH/883B | –55°C to +125°C | Header | H-10A |

NOTE
[1]"S" grade chips are available tested at +25°C and +125°C. "J" grade chips are also available.

**STANDARD CONNECTION**

The AD536A is simple to connect for the majority of high accuracy rms measurements, requiring only an external capacitor to set the averaging time constant. The standard connection is shown in Figure 1. In this configuration, the AD536A will measure the rms of the ac and dc level present at the input, but will show an error for low frequency inputs as a function of the filter capacitor, $C_{AV}$, as shown in Figure 5. Thus, if a 4 µF capacitor is used, the additional average error at 10 Hz will be 0.1%, at 3 Hz it will be 1%. The accuracy at higher frequencies will be according to specification. If it is desired to reject the dc input, a capacitor is added in series with the input, as shown in Figure 3, the capacitor must be nonpolar. If the AD536A is driven with power supplies with a considerable amount of high frequency ripple, it is advisable to bypass both supplies to ground with 0.1 µF ceramic discs as near the device as possible.

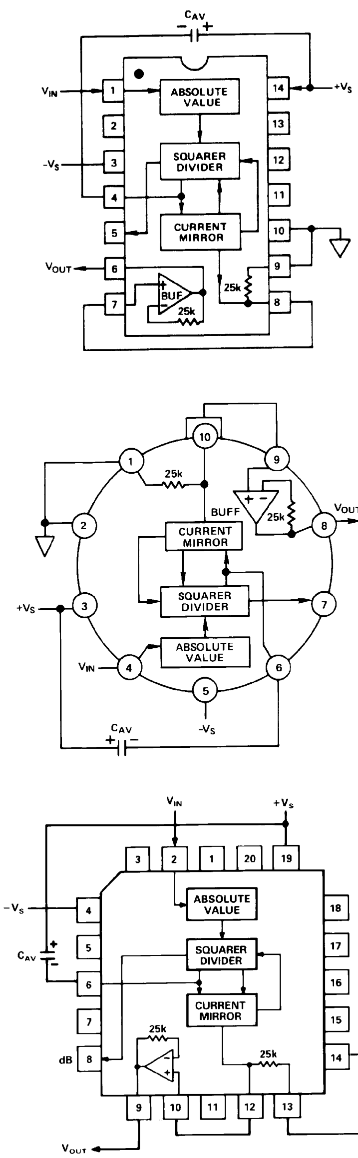



*Figure 1. Standard RMS Connection*

The input and output signal ranges are a function of the supply voltages; these ranges are shown in Figure 14. The AD536A can also be used in an unbuffered voltage output mode by disconnecting the input to the buffer. The output then appears unbuffered across the 25k resistor. The buffer amplifier can then be used for other purposes. Further the AD536A can be used in a current output mode by disconnecting the 25k resistor from ground. The output current is available at Pin 8 (Pin 10 on the "H" package) with a nominal scale of 40 µA per volt rms input positive out.

## OPTIONAL EXTERNAL TRIMS FOR HIGH ACCURACY

If it is desired to improve the accuracy of the AD536A, the external trims shown in Figure 2 can be added. R4 is used to trim the offset. Note that the offset trim circuit adds 365 Ω in series with the internal 25 kΩ resistor. This will cause a 1.5% increase in scale factor, which is trimmed out by using R1 as shown. Range of scale factor adjustment is ±1.5%.

The trimming procedure is as follows:

1. Ground the input signal, $V_{IN}$, and adjust R4 to give zero volts output from Pin 6. Alternatively, R4 can be adjusted to give the correct output with the lowest expected value of $V_{IN}$.
2. Connect the desired full scale input level to $V_{IN}$, either dc or a calibrated ac signal (1 kHz is the optimum frequency); then trim R1, to give the correct output from Pin 6, i.e., 1000 V dc input should give 1.000 V dc output. Of course, a ±1.000 V peak-to-peak sine wave should give a 0.707 V dc output. The remaining errors, as given in the specifications are due to the nonlinearity.

The major advantage of external trimming is to optimize device performance for a reduced signal range; the AD536A is internally trimmed for a 7 V rms full-scale range.

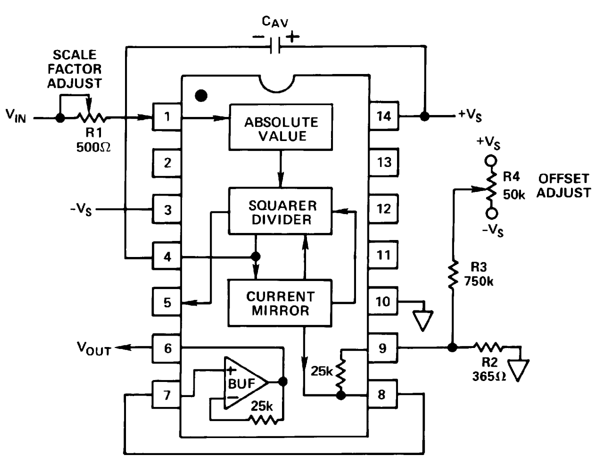



*Figure 2. Optional External Gain and Output Offset Trims*

## SINGLE SUPPLY CONNECTION

The applications in Figures l and 2 require the use of approximately symmetrical dual supplies. The AD536A can also be used with only a single positive supply down to +5 volts, as shown in Figure 3. The major limitation of this connection is that only ac signals can be measured since the differential input stage must be biased off ground for proper operation. This biasing is done at Pin 10; thus it is critical that no extraneous signals be coupled into this point. Biasing can be accomplished by using a resistive divider between $+V_S$ and ground. The values of the resistors can be increased in the interest of lowered power consumption, since only 5 mA of current flows into Pin 10 (Pin 2 on the "H" package). AC input coupling requires only capacitor C2 as shown; a dc return is not necessary as it is provided internally. C2 is selected for the proper low frequency break point with the input resistance of 16.7 kΩ; for a cutoff at 10 Hz, C2 should be 1 µF. The signal ranges in this connection are slightly more restricted than in the dual supply connection. The input and output signal ranges are shown in Figure 14. The load resistor, $R_L$, is necessary to provide output sink current.

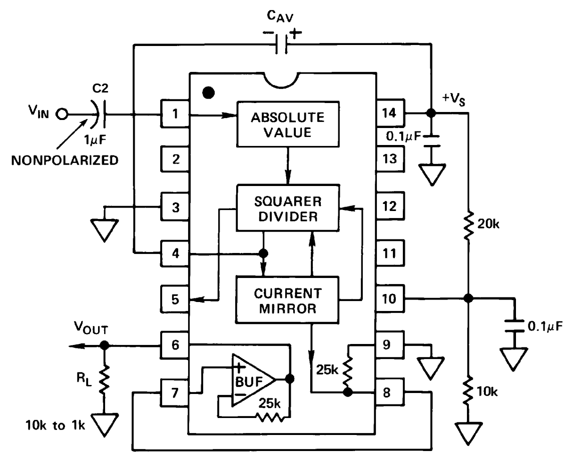



*Figure 3. Single Supply Connection*

## CHOOSING THE AVERAGING TIME CONSTANT

The AD536A will compute the rms of both ac and dc signals. If the input is a slowly-varying dc signal, the output of the AD536A will track the input exactly. At higher frequencies, the average output of the AD536A will approach the rms value of the input signal. The actual output of the AD536A will differ from the ideal output by a dc (or average) error and some amount of ripple, as demonstrated in Figure 4.

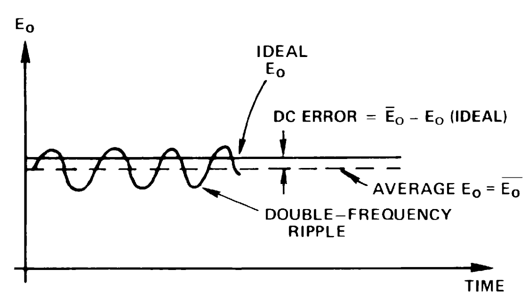



*Figure 4. Typical Output Waveform for Sinusoidal Input*

The dc error is dependent on the input signal frequency and the value of $C_{AV}$. Figure 5 can be used to determine the minimum value of $C_{AV}$ which will yield a given percent dc error above a given frequency using the standard rms connection.

The ac component of the output signal is the ripple. There are two ways to reduce the ripple. The first method involves using a large value of $C_{AV}$. Since the ripple is inversely proportional to $C_{AV}$, a tenfold increase in this capacitance will affect a tenfold reduction in ripple. When measuring waveforms with high crest

factors, (such as low duty cycle pulse trains), the averaging time constant should be at least ten times the signal period. For example, a 100 Hz pulse rate requires a 100 ms time constant, which corresponds to a 4 μF capacitor (time constant = 25 ms per μF).

The primary disadvantage in using a large $C_{AV}$ to remove ripple is that the settling time for a step change in input level is increased proportionately. Figure 5 shows that the relationship between $C_{AV}$ and 1% settling time is 115 milliseconds for each microfarad of $C_{AV}$. The settling time is twice as great for decreasing signals as for increasing signals (the values in Figure 5 are for decreasing signals). Settling time also increases for low signal levels, as shown in Figure 6.

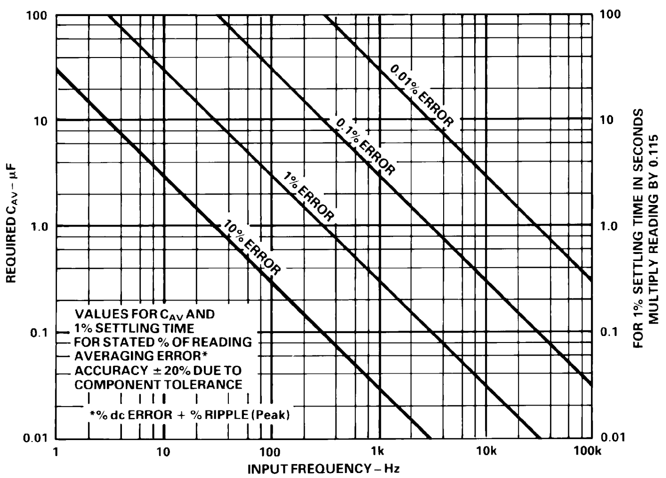



*Figure 5. Error/Settling Time Graph for Use with the Standard rms Connection in Figure 1*

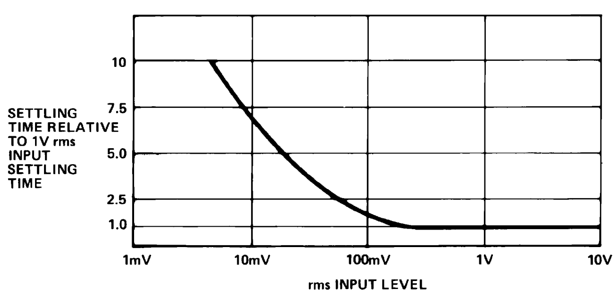



*Figure 6. Settling Time vs. Input Level*

A better method for reducing output ripple is the use of a "post-filter." Figure 7 shows a suggested circuit. If a single-pole filter is used (C3 removed, $R_X$ shorted), and C2 is approximately twice the value of $C_{AV}$, the ripple is reduced as shown in Figure 8 and settling time is increased. For example, with $C_{AV}$ = 1 μF and C2 = 2.2 μF, the ripple for a 60 Hz input is reduced from 10% of reading to approximately 0.3% of reading. The settling time, however, is increased by approximately a factor of 3. The values of $C_{AV}$ and C2, can, therefore, be reduced to permit faster settling times while still providing substantial ripple reduction.

The two-pole post-filter uses an active filter stage to provide even greater ripple reduction without substantially increasing the settling times over a circuit with a one-pole filter. The values of $C_{AV}$, C2, and C3 can then be reduced to allow extremely fast settling times for a constant amount of ripple. Caution should be exercised in choosing the value of $C_{AV}$, since the dc error is dependent upon this value and is independent of the post filter.

For a more detailed explanation of these topics refer to the *RMS to DC Conversion Application Guide 2nd Edition*, available from Analog Devices.

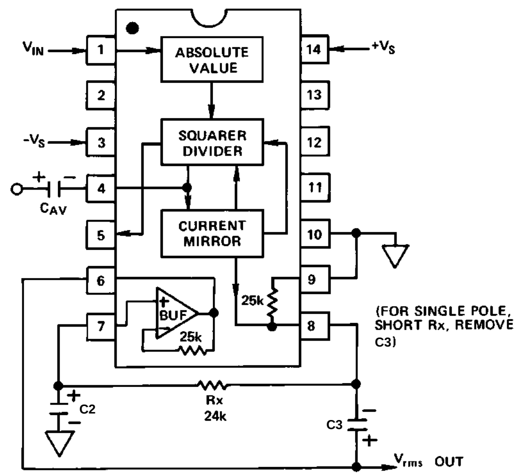



*Figure 7. 2-Pole "Post" Filter*

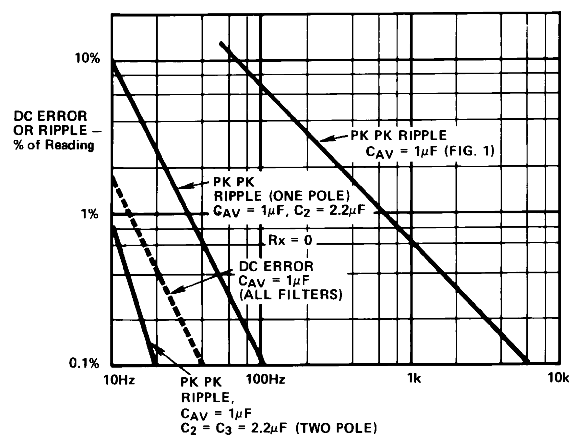



*Figure 8. Performance Features of Various Filter Types*

## AD536A PRINCIPLE OF OPERATION

The AD536A embodies an implicit solution of the rms equation that overcomes the dynamic range as well as other limitations inherent in a straightforward computation of rms. The actual computation performed by the AD536A follows the equation:

$$V\,rms = Avg.\left[\frac{V_{IN}^{2}}{V\,rms}\right]$$

Figure 9 is a simplified schematic of the AD536A; it is subdivided into four major sections: absolute value circuit (active rectifier), squarer/divider, current mirror, and buffer amplifier. The input voltage, $V_{IN}$, which can be ac or dc, is converted to a unipolar current $I_1$, by the active rectifier $A_1$, $A_2$. $I_1$ drives one input of the squarer/divider, which has the transfer function:

$$I_4 = I_1^2/I_3$$

The output current, $I_4$, of the squarer/divider drives the current mirror through a low-pass filter formed by R1 and the externally connected capacitor, $C_{AV}$. If the R1, $C_{AV}$ time constant is much greater than the longest period of the input signal, then $I_4$ is effectively averaged. The current mirror returns a current $I_3$, which equals Avg. $[I_4]$, back to the squarer/divider to complete the implicit rms computation. Thus:

$$I_4 = Avg.\left[I_1^2/I_4\right] = I_1\ rms$$

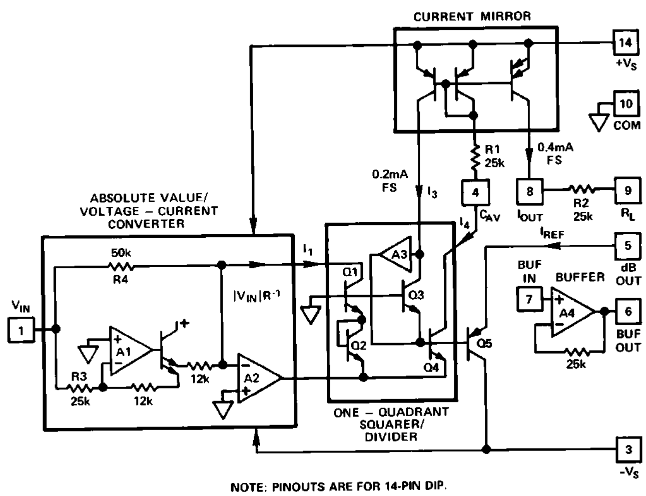



*Figure 9. Simplified Schematic*

The current mirror also produces the output current, $I_{OUT}$, which equals $2I_4$. $I_{OUT}$ can be used directly or converted to a voltage with R2 and buffered by A4 to provide a low impedance voltage output. The transfer function of the AD536A thus results:

$$V_{OUT} = 2R2\ I\ rms = V_{IN}\ rms$$

The dB output is derived from the emitter of Q3, since the voltage at this point is proportional to –log $V_{IN}$. Emitter follower, Q5, buffers and level shifts this voltage, so that the dB output voltage is zero when the externally supplied emitter current ($I_{REF}$) to Q5 approximates $I_3$.

**CONNECTIONS FOR dB OPERATION**

A powerful feature added to the AD536A is the logarithmic or decibel output. The internal circuit computing dB works accurately over a 60 dB range. The connections for dB measurements are shown in Figure 10. The user selects the 0 dB level by adjusting R1, for the proper 0 dB reference current (which is set to exactly cancel the log output current from the squarer-divider at the desired 0 dB point). The external op amp is used to provide a more convenient scale and to allow compensation of the +0.33%/°C scale factor drift of the dB output pin. The special T.C. resistor, R2, is available from Tel Labs in Londonderry, N.H. (model Q-81) or from Precision Resistor Inc., Hillside, N.J. (model PT146). The averaged temperature coefficients of resistors R2 and R3 develop the +3300 ppm needed to reverse compensate the dB output. The linear rms output is available at Pin 8 on DIP or Pin 10 on header device with an output impedance of 25 kΩ; thus some applications may require an additional buffer amplifier if this output is desired.

dB Calibration:

1. Set $V_{IN}$ = 1.00 V dc or 1.00 V rms
2. Adjust R1 for dB out = 0.00 V
3. Set $V_{IN}$ = +0.1 V dc or 0.10 V rms
4. Adjust R5 for dB out = –2.00 V

Any other desired 0 dB reference level can be used by setting $V_{IN}$ and adjusting R1, accordingly. Note that adjusting R5 for the proper gain automatically gives the correct temperature compensation.

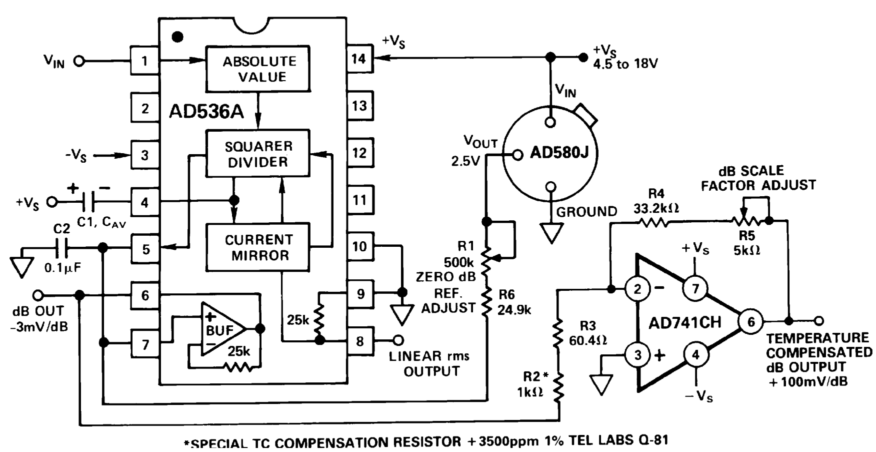



*Figure 10. dB Connection*

## FREQUENCY RESPONSE

The AD536A utilizes a logarithmic circuit in performing the implicit rms computation. As with any log circuit, bandwidth is proportional to signal level. The solid lines in the graph below represent the frequency response of the AD536A at input levels from 10 millivolts to 7 volts rms. The dashed lines indicate the upper frequency limits for 1%, 10%, and 3 dB of reading additional error. For example, note that a 1 volt rms signal will produce less than 1% of reading additional error up to 120 kHz. A 10 millivolt signal can be measured with 1% of reading additional error (100 µV) up to only 5 kHz.

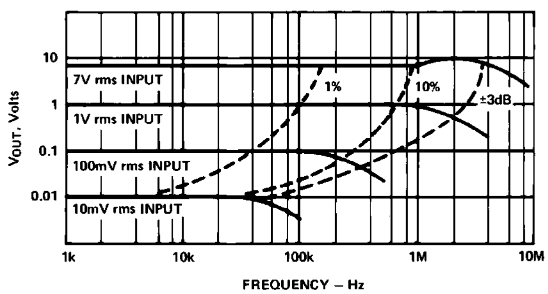



*Figure 11. High Frequency Response*

## AC MEASUREMENT ACCURACY AND CREST FACTOR

Crest factor is often overlooked in determining the accuracy of an ac measurement. Crest factor is defined as the ratio of the peak signal amplitude to the rms value of the signal (CF = $V_P$/ V rms). Most common waveforms, such as sine and triangle waves, have relatively low crest factors (<2). Waveforms which resemble low duty cycle pulse trains, such as those occurring in switching power supplies and SCR circuits, have high crest factors. For example, a rectangular pulse train with a 1% duty cycle has a crest factor of 10 (CF = $1\sqrt{\eta}$).

Figure 12 is a curve of reading error for the AD536A for a 1 volt rms input signal with crest factors from 1 to 11. A rectangular pulse train (pulse width 100 µs) was used for this test since it is the worst-case waveform for rms measurement (all the energy is contained in the peaks). The duty cycle and peak amplitude were varied to produce crest factors from 1 to 11 while maintaining a constant 1 volt rms input amplitude.

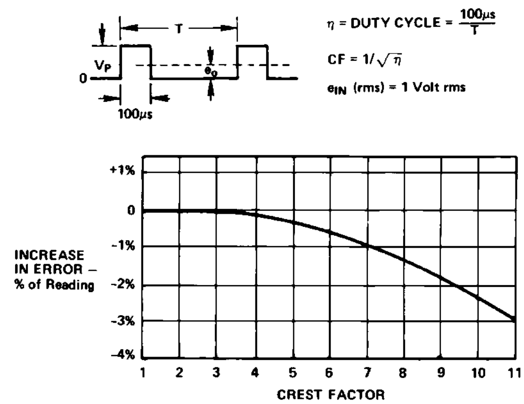



*Figure 12. Error vs. Crest Factor*

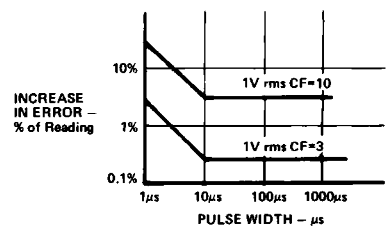



*Figure 13. AD536A Error vs. Pulse Width Rectangular Pulse*

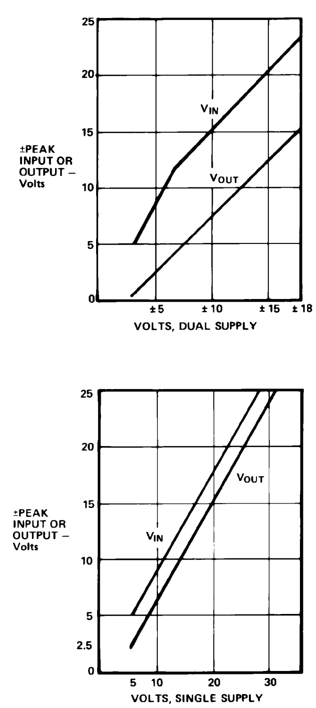
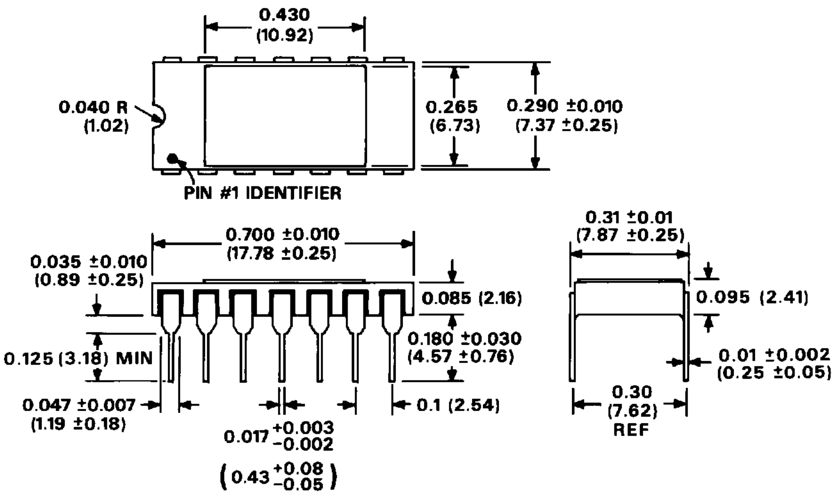



*Figure 14. AD536A Input and Output Voltage Ranges vs. Supply*

## OUTLINE DIMENSIONS

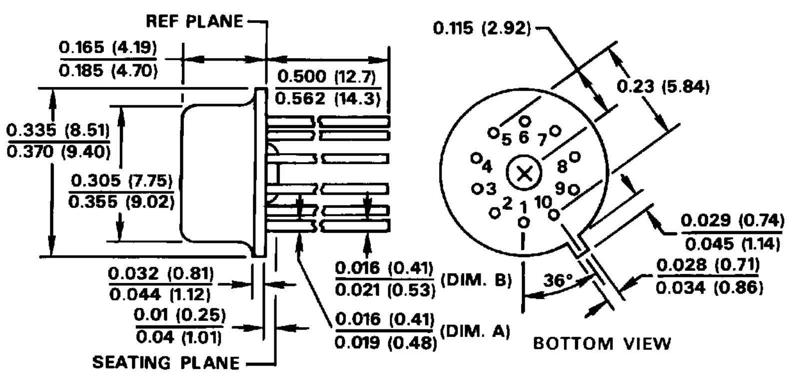
Dimensions shown in inches and (mm).

### D-14 Package
### TO-116

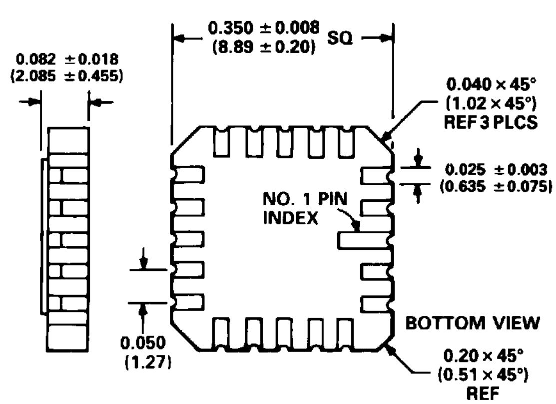



C502d–20–9/88

### H-10A Package
### TO-100




### E-20A Package
### LCC




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